



**After the KC-135, What Next?
Exploring the Future Capabilities and
Acquisition Of Our Next Generation Tanker**

GRADUATE RESEARCH PROJECT

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Preface and Acknowledgements

This research was initiated for two reasons. First, as an officer with a background in airlift and special operations, I wanted to research a subject that would help me learn more about the aerial refueling portion of Air Mobility Command. Second, it initially seemed that combining military and commercial markets for future aerial refueling and airlift would be a natural solution to our continuing tanker shortfalls. The incredible advances on the horizon for our tanker force is exciting and humbling in their complexity. I can honestly say I learned more about the tanker portion of Air Mobility Command than I imagined I could.

On a more personal note, I owe a great deal to the many people who helped me complete this educational effort. My advisor, Major Mike Rehg, provided crucial focus and content guidance. He provided succinct, pertinent recommendations that made this paper more complete and greatly improved its format. The Air Mobility Warfare Center Research Librarian, Ms. Janice Missildine, was an immense help in mining data on many aspects of this paper. Her incredible knowledge of research databases provided the jump-off point for me on many occasions, and her ability to obtain hard copies of research material on short notice allowed me to spend more time culling insights from the data rather than wading through immense volumes of paper.

I must ultimately give my greatest thanks to my family. My kids have weathered thirteen months of only seeing Dad on weekends. They continually prove to me how lucky I am and I am very proud of them. Finally, no one has worked harder to support me this past year than my wife. I am most grateful to her for her love and patience, not to mention the steady, courageous manner in which she has supported our family during my

countless nights of absence. Any success I achieve in the Air Force will be due to, in no small part, the support of my family and I am grateful.

Abstract

The basic research question is: What future capabilities will be necessary in tomorrow's Air Force tanker to meet the sophisticated and complicated needs of the military into the 21st century? To answer this question I studied the military and commercial markets for current and future aerial refueling technologies. I also looked at industry efforts in the way of advanced airframe concepts. The Boeing 767 Tanker and the Air Force "Smart Tanker" concepts were examined for insights into what our future tanker will be required to do and what additional technologies it will contain. My immediate reaction to the Air Force's current situation would be focused determination. Air Force leadership realizes the tightrope they are walking. The aerial refueling portion of Air Mobility Command has held the key to almost every major conflict in the last 40 years. The military's success over the last five major conflicts was significantly altered, improved or affected by our ability to properly refuel our bombers, fighters and even our strategic mobility assets. The events precluding the United States entering our current "War on Terrorism" have essentially focused our national resolve on providing our military with the assets needed to be successful. This has created an unprecedented amount of bi-partisan support for upgrading our tanker force. The only questions are what do we buy and how can we ensure that the proper technology is incorporated to provide a tanker of the future, because we know that warfare of the future will not be traditional. We must be able to adapt and create the battlefield necessary to face and defeat any and all enemies, no matter how illusive.

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Chapter 1 - Issue and Importance

Basic Research Question: *What future capabilities will be necessary in tomorrow's Air Force tanker to meet the sophisticated and complicated needs of the Air Force and the military into the 21st century?*

The military's current aerial refueling capabilities and its future is one of today's hottest topics. You only have to peruse any military-focused periodical or magazine and you will almost certainly come across multiple articles on the subject. Whether the article focuses on the current problems with the Air Force's KC-135 tanker fleet or exactly how we will eventually replace it, the topic is definitely of interest to the highest levels of today's military. But one fact that is not disputed is the increased importance of the United States' ability to project power, especially since the attack on the World Trade Center in September 2001. Projecting power is the arena of today's Air Force, and the critical enabler of our forces to successfully project power is Air Mobility Command's tanker aircraft fleet. According to AFDD 2-6.2, "While air refueling has been the key element in modern airpower employment, force downsizing, a reduction in overseas presence, and increased global responsibilities have brought a need for robust, flexible, and versatile air refueling force." (AFDC/DR, 1999)

During a war, air mobility delivers the bulk of the initial time-critical forces and supplies, and it is the cornerstone for the nation's security strategy for the foreseeable future. The military's KC-135 and the KC-10 aircraft are expected to refuel these airlift aircraft in transit. (GAO, 2000: 6-7) Demand on tanker assets has significantly increased during Operation Enduring Freedom.

"During the heaviest bombing in the opening weeks of the war, 30 to 35 tankers were in the air, nearly round the clock, to refuel 100 tactical jets. That fleet included B-52 and B-1 bombers coming from the island of

Diego Garcia, 3,000 miles away in the Indian Ocean, Navy fighters flying off carriers in the Arabian Sea almost 700 miles from Kabul, and Air Force fighters flying 1,400 miles from Kuwait to Qatar.” (Loeb, 2002)

In comparison, during the Gulf war carriers were only 350 miles from Baghdad. Carriers in the Arabian Sea, by comparison, are twice as far from Kabul and even further from the northern cities of Afghanistan. The distances for the bombers is even greater, considering they are departing from and returning to Diego Garcia – a distance equivalent to taking off from New York and bombing Los Angeles before returning home. “Not one of those bombers or fighters would have gotten in and out without a tanker,” says Col. James R. Pugh, the vice commander of the 305th Air Mobility Wing at McGuire Air Force Base in New Jersey. (Loeb, 2002)

Currently, the Air Force maintains a fleet of 605 tanker aircraft, including 546 KC-135s and 59 KC-10s. Of these 605 tankers only 520 are available to accomplish the mission. The rest are reserved for backup and training purposes. Both the KC-10s and the KC-135s mission capable rates are closely watched. The Air Force requires a mission capable rate of at least 85% to be considered satisfactory for accomplishing the mission. Currently the KC-135 is hovering around 67% and the KC-10 is approximately 88%. Even though the KC-10s rate is above the desired goal of 85% it is still closely watched due to its greater importance – it is capable of providing aerial refueling as well as airlift capability. (GAO, 2000: 30)

Table 1. Mission Capable Rates.

Type of Aircraft	Total Number of Aircraft	Total mission authorized aircraft	Standard mission capable rates	Equivalent number of aircraft needed	Equivalent number of aircraft mission capable	Average aircraft mission capable rates	Number of aircraft short (over)
KC-135	546	472	85	402	317*	67*	85*
KC-10	59	48	85	41	42	88	-1

* Air Mobility Command only tracks 442 KC-135 authorized aircraft and 30 KC-135s are assigned to other commands. The 67 percent average mission capable rate for 442 aircraft was used to compute the mission capable numbers for all 472 aircraft. (GAO, 2000: 30)

Ultimately, the average number of refueling aircraft mission capable is nearly 19 percent short. Measured differently, the aerial refueling shortfall equals about 14 percent of the 106.1 million pounds of fuel per day total capacity.

Table 2. Refueling Capacity Shortfall

Mission	Military wartime requirement	Current peacetime capability*	Shortfall (overage)	Percent total shortfall (overage)
KC-135	402 aircraft	317 aircraft	85 aircraft	19.19
KC-10	41 aircraft	42 aircraft	(1) aircraft	-0.23
Total refueling aircraft	443 aircraft	359 aircraft	84 aircraft	18.96
KC-135	74.8 MPF/D	59.0 MPF/D	15.8 MPF/D	14.9
KC-10	31.3 MPF/D	32.4 MPF/D	(1.1) MPF/D	-1
Total refueling capacity	106.1 MPF/D	91.4 MPF/D	14.7 MPF/D	13.9

* Averages for KC-10 and KC-135 were based on fiscal years 1997-99.

Source: Based on US Air Force, Air Mobility Command data.

(GAO, 2000)

Air Mobility Command, as recently as 2000, claimed the current number of refueling aircraft, while less than the classified requirement identified in 1996, was acceptable, assuming the aircraft could be shifted between the planned-for nearly simultaneous major conflicts. Air Mobility Command's determination of aerial refueling requirements and the ability of these forces to meet demand are based on the aircraft operating at standard wartime mission capable rates – the percentage of aircraft expected to be mission capable. But, during 1997-99, the KC-135s average mission capable rates

did not meet this standard and the KC-10 rate was only slightly better than the requirement. It was believed that the current Tanker Requirements Study 2005 (TRS05) might call for an increase in the number of tanker aircraft. As of yet TRS05 is still classified. Nevertheless, Air Mobility Command officials say the cost to replace the 546 KC-135s would be significant, and at a pace of 15 to 20 aircraft a year, it could take a substantial period of time. (GAO, 2000: 18)

Air Mobility Command's pre-September 11 stated goal was to sustain the fleet by replacing the KC-135 with a new refueling aircraft (originally labeled KC-X) beginning in about fiscal year 2013. As recently as June 2001, General Charles Robertson, Commander, US Transportation Command, claimed the recent TRS05 determined the current 600 tanker refueling fleet would remain valid. He additionally highlighted the Air Force's current tanker aircrew shortfall, currently equal to 75 aircrew short of meeting high-tempo air activity or an air war. General Robertson also said a recent KC-135 economic service life study validated the potential of maintaining the KC-135s through 2040 if need be. (Sirak, 2001) The Mobility Air Forces (MAF) capability statement for air refueling in MAF's Strategic Plan 2002 states, "Provide the capability to refuel, in-flight, multiple aerospace vehicles simultaneously, across the spectrum of conflict and in all operating environments." A robust air refueling capability is a critical enabler for US military and allied/coalition air power. The aging KC-135 aircraft availability problems and rising costs, associated with maintaining an aging fleet, place this crucial capability in jeopardy. (AMC/XPR, 2002: 8) With the increased usage of the aircraft in Operation Enduring Freedom and the apparent reversal of position by Air Mobility Command, these plans may have to be upgraded.

TRS-05 also endorses the theory that continued successful mission accomplishment of crucial air refueling responsibility is at risk due to increasing demands and decreasing availability as a result of aging aircraft. Corrosion, major structural repairs, and increasing inspections are major drivers in the increase in costs and time spent in depot. Although depot improvements should result in a reduced depot time and increased availability, the study predicts availability will again decline when the tanker reaches 50 years old. In addition, tankers do not have the required connectivity to command and control agencies needed in today's conflicts.(AMC/XPR, 2002: 12)

The Boeing 707, which is the platform used for the KC-135, is a converted long-range civilian airliner. It was originally outfitted with four Pratt and Whitney JT3D engines on the D and E models. On a majority of the KC-135s this was later upgraded to the KC-135R Model which are powered by four CFM56 (military designation F108) engines which provide significantly better thrust and fuel efficiency while at the same time increase range, altitude and performance factors. These new engines are also more reliable than the older JT3D engines. There are still many older E models in the inventory, particularly with the guard and reserves.

Depending on the current military situation the tanker fleet is utilized at different percentages on large, long-range cargo aircraft (non-shooters) versus fighter/bomber type aircraft (shooters). The majority of peacetime aerial refueling is for the non-shooter aircraft. But during contingencies, like an Air Expeditionary Force (AEF) swap-out, the percentages even out to a more 50/50 split between the two types. But the percentages lean in the other direction during wartime. Non-shooter aircraft aerial refueling takes a backseat to the shooter aerial refueling requirement. Cargo aircraft aerial refueling

percentage falls to about 10 percent during wartime or a space available basis.

Military strategy is built around the number of booms (refueling points) available in the air for a given mission. Therefore a very important capability to consider is the ability of a tanker to be able to refuel multiple aircraft. The KC-135 is equipped with a centerline boom capable of refueling any Air Force aircraft. Additionally, with some prior notice a hose-and-drogue system can be installed to refuel non-boom equipped aircraft, such as Navy fighters, NATO or European aircraft not boom equipped. The US Air Force adopted the boom system during the Cold War to facilitate Strategic Air Command's nuclear projection strategy, which required large amounts of aerial refueling to get its bombers to Russia in minimum time. The boom system can transfer fuel approximately three to four times as quickly as the hose and drogue system, depending on the type of hose and drogue system being compared. This was considered necessary to refuel the largely fuel inefficient bomber aircraft used to deliver this nuclear strike. Outside the Air Force, fighter aircraft largely use the hose-and-drogue because of the ease of hook up and the relatively small amount of fuel required by them. But bomber and transport aircraft require large amounts of fuel for certain missions. For example, a C-5 Galaxy could easily require 80 to 100 thousand pounds of fuel during a normal contingency aerial refueling whereas a fighter could fill its tanks with only several thousand pounds. With such a small amount to be transferred, the fighter could still get its gas in only a few minutes, even with the slower transfer rate delivered by the drogue. Currently the boom versus drogue system for the KC-135 is an either/or option. Transfer between the two systems while in the air is not possible and requires approximately 30 minutes for ground personnel to install the hose and drogue system. A new system called

the Multi-Point Refueling System (MPRS) has been developed which installs wingtip hose and drogue air refueling pods capable of refueling two aircraft simultaneously. The program was developed in 1998 and originally 45 KC-135R models were to be modified. Four were installed in 1999 and six airplanes per year were scheduled for modification until all 45 aircraft were outfitted. Currently, there have been less than 15 modified and the success rate for utilization is not very promising. Most are not even being used as a primary refueling method due to several problems with wing-tip turbulence. (Huxsoll, 1999)

Another consideration is the large number of 707 derivatives currently used by the Air Force. Currently the Air Force has seven versions of the 707 in its inventory. They include the KC-135 (Refueler), the E-3 Sentry (Airborne early warning aircraft), the E-8 JSTARS (Joint surveillance and target attack radar aircraft), C-135 (transport aircraft), EC-135 (Airborne command post relay aircraft), RC-135 (Electronic reconnaissance aircraft), and the VC-137 (VIP transport). Were the Air Force to begin to phase out the KC-135, the aircraft taking its place could eventually be considered as a replacement for these current airframes and missions. In the case of the Boeing 767 it could also be considered for the aero-medical role, since there is already an aero-medical modification available for the 767 aircraft. It was developed for certain Civil Reserve Air Fleet (CRAF) aircraft. (Jane's, 2001-02)

When it comes to a replacement tanker, there are several competing objectives to consider. Do we want a larger aircraft that carries more fuel than the KC-135, ultimately extending its range and refueling capacity? Should it have hose-and-drogue capability as well as boom technology? Should we replace the aircraft on a one-to-one basis

regardless of the fuel capacity of the new tanker? If not, what is the right balance between individual tanker fuel capacity and total number of airframes required? Should the Air Force consider the trade-offs of buying an already established commercial aircraft, like the 767, versus the development of a new prototype tanker aircraft designed to accomplish all the requirements of tomorrow's Air Force? Can we afford to expend the time and money to develop a new tanker from scratch? Have we already let the KC-135 fleet surpass its useful life where it needs immediate replacement, effectively eliminating the time needed to develop a next generation tanker from the ground up? How about the current infrastructure? We must consider costs associated with different size aircraft and newer systems. Either option would require initial investment in hangars, maintenance, personnel, training and other unforeseen expenses. Finally, how do we determine all these answers and also decide what capabilities this new aircraft **must** possess?

This paper explores the future of the Air Force's tanker assets. Although this paper doesn't spend extraordinary time on proving the inadequacy of the current KC-135 system, shortcomings will be highlighted only in the context of showing what options we have for the future and determining what future system or capabilities would be most beneficial for the Air Force and its customers. I will use our current data on the KC-135 to flush out several options for the Air Force to consider, as well as form a baseline of capabilities that should be met by whatever final options are chosen. I will explore the current commercial market for "buying" pay-by-the-hour contract air refueling capability as well as current off-the-shelf aircraft options – considering the tanker aircraft history has historically trended toward commercial airliner derivatives. I will also explore

industry initiatives for a future development tanker and how and when they could be implemented. This will include but not be limited to future box-wing and blended-wing technology as well as an expanded dual-role tanker/airlift type mission. This dual role concept is not new (KC-10 is a very capable dual role airlift/tanker platform) and would seem to be the future of the Air Force. Secretary Roche has been quoted saying that there will never be another single role aircraft acquired due to the requirement for cost and capability efficiencies in today's Air Force. Therefore, I will also spend some time exploring what other roles the future "KC-X" could be used for and what advantages it would provide.

Chapter 2 -- Literature Review

A thorough and exhaustive literature study has been performed during this research project. Sources include trade journals, defense technical papers, various books and periodicals, other research papers, and world-wide web resources.

2.1 History

The KC-135 Stratotanker was originally developed in 1954 by Boeing engineers from a Boeing 707 platform. Boeing is still the only manufacturer of the flying boom used by most Air Force aircraft for refueling. They developed the technology for the Air Force during the 1950's to facilitate Strategic Air Command's strategy of nuclear deterrence using their long-range bombers with refueling to attack the Soviet Union. Today, most tanker derivatives in the world are 707 derivatives. Boeing officially discontinued manufacture of the KC-135 in 1991 after building over 700. A re-engine program to replace the KC-135s obsolete turbojet engines with more powerful, more efficient high-bypass turbofans – creating the KC-135R model, replaced this program. Boeing has been approached about possible future upgrades to the 707 to extend its operating life for 20 to 40 more years. Boeing's Military Aerospace Support spokesman, Paul Guse, responded by saying the 707 line has long been discontinued and may not be the best platform for the Air Force to place its trust in for that long of a time. Boeing touts their 767 as a replacement for the KC-135. The company says the 767 is in plentiful supply and is well supported into the next decade by a "support infrastructure worldwide" and would be a much wiser choice for the Air Force. (Harris, 2001) I will discuss this option further in the Findings section of this report.

2.2 Current KC-135 Problems

The KC-135 has a very distinguished career, but now has a myriad of problems. Aside from the extremely low mission capable rate, previously mentioned, a basic fact to consider is the age of the KC-135 fleet. The average age of the KC-135 fleet is 41 years. Aside from the B-52, which is several years older, this is the oldest fleet of aircraft in the Air Force inventory. The very fact that most of the KC-135's are over 40 years old is a contributing factor to the problems it has had in maintaining its required mission capable rate. A major factor in the shortfall, and a directly attributable to the age of the aircraft, is the significantly increased depot time required to maintain the airworthiness of the fleet. For example, from fiscal years 1992 through 1999, the average number of days for KC-135s to complete depot maintenance more than doubled, from 170 days to 374 days due to a re-work of the wings and other structural items, corrosion prevention measures, and rewiring. Significantly adding to the depot time problem is the KC-135s antiquated avionics. In addition to all the structural maintenance, the Air Force has implemented a couple of upgrades to the aircraft. First, was PACER CRAG, which upgraded the navigation system of the aircraft allowing the crew to be reduced to two pilots and a boom operator. Additionally, in response to stricter air traffic control standards on high traffic airways, like those in the North Atlantic and Europe, the KC-135s avionics required upgrading to become GATM compliant. Without this upgrade they will lose their ability to use certain altitudes along these routes. Without compliance even more wear and tear will be inflicted on these aging airplanes as they are routed around the prime air routes. There is also some doubt whether the technology is available to bring the aircraft into compliance with these stricter guidelines. GATM requires significant

upgrades in course and altitude precision as well as sensing equipment for other aircraft in the airspace. The age of the KC-135 has increased doubt that such high-tech equipment could ever be installed to meet the standards. Boeing has expressed doubts the version of the 707 used for the KC-135s would ever be able to pass standards for GATM compliance. (Fedors, 2001)

Table 3. Aircraft Depot Averages

		Number of aircraft in depot (monthly average)	
Aircraft type	Average age (yrs)	Planned	Actual
C-5	23	16	36
KC-135	41	52	124*
KC-10	17	5	10

* Approximately 16 aircraft per quarter were undergoing a one-time avionics modification.

Source: U.S. Air Force, Air Mobility Command (GAO, 2000)}.

Another problem contributing to the long depot times and the low mission capable rates is the lack of spare parts. Historically, the older a plane gets the more parts are required to maintain it. The Air Force has consistently under-funded the acquisition program for spare parts. In fact they have fully funded its total requirement for spare parts only twice – in fiscal years 1995 and 1999. Over time many single manufacturers of specific parts go out of business or just quit making the parts they consider unprofitable. This results in the Air Force having to acquire new sources. These acquisition programs are difficult and exponentially more expensive due to the small number of parts needed and the lack of competition to regulate prices. This is a problem faced by many old weapon systems in today's military. A lack of spare parts also increases the

cannibalization rate from other aircraft causing even further degradation of the fleet's mission capable rate.

Table 4. Parts Supply and Depot Rates

	Not mission capable for supply rate*		Number of aircraft in depot (monthly average)**	
Aircraft type	Average	Standard	Average	Standard
C-5	17.75	8.5	54.93	19.6
KC-135	12.65	8.5	11.05	4
KC-10	4.47	5	4.51	3

* Percentage of aircraft that cannot meet mission requirements because they lack parts.

** Number of cannibalizations per 100 flights.

Source: U.S. Air Force, Air Mobility Command (GAO, 2000: 13, 14)

Adding to the KC-135 problems is the increased use of the fleet in Operation Enduring Freedom. Although previous to September 11 the Air Force focused on maintaining the KC-135s for 20 to 40 more years, in light of recent increased operations tempo and the increasing evidence that this trend will continue into the future, we must be prepared to explore the problems faced by the Air Force in the arena of competing objectives. The Air Force is funding many aircraft upgrades and new acquisition programs at the present time. They include the Joint Strike Fighter and the F-22 as well as the very expensive C-17 program that recently increased its final number to 180 aircraft. These projects leave very little money for acquiring new tankers, considering the vast numbers that would be required for a complete one-for-one replacement of the KC-135 fleet. (GAO, 2000: 13, 14)

2.3 Estimates of Capability Shortage

The variations in current estimates suggest that quantifying a shortage is more an assumption than a scientific fact. Estimates vary depending on the source. The military wartime requirement for aerial refueling aircraft is 443 aircraft. Our current peacetime capability is 359 aircraft. This results in an almost 19 percent shortfall, based on 1997-99 numbers. (GAO, 2000: 10) Simple and concise, these numbers show that anyone could look up the requirement for aerial refueling and compare this number to the available amount and determine there is a shortfall. The Air Force has many plans to remedy this situation, from buying/leasing new planes to lowering the wartime requirements by changing the wording in Air Force doctrine. The Air Force remedy may work, only time will tell, but it is imperative that the military focus on this problem. Very few assets in our military today affect so many other military strategies as our tankers. Although the health of our tanker force is in the top five of the wish list put forward by the Chairman of the Joint Chiefs of Staff to Congress, that may not be high enough if our abilities continue to deteriorate.

2.4 Worldwide Tanker Market

What is the market for tanker aircraft throughout the world? Currently various versions of the Boeing 707 are used as tanker aircraft in over 20 different countries, albeit not to the extent that they are used in the United States. Most of these countries operate less than ten total tankers and only a handful use the boom system adopted by the US Air Force. Many of these countries have other versions of tanker aircraft, such as Britain's VC-10 and Tristar tankers, both of which can be used in a passenger/cargo role also. Several countries are looking to upgrade their tanker force but, suffice it to say that, cost

is a major obstacle. Were the US Air Force to proceed into the acquisition of a new tanker, many of these countries could be counted on to replace their few tankers with newer versions of whatever the United States chooses. There are two reasons for this. The first reason is purely economical. Should the United States replace their vast fleet of tankers, the platform they choose would become significantly less expensive for other nations, considering the large number being produced, especially if the platform was a commercial off-the-shelf version of a civilian airliner. Second, it is much easier to interfly with NATO forces if you have compatible aircraft. Any tanker the Air Force purchases would, more than likely, be compatible with NATO aircraft and would allow these countries to participate in multi-nation exercises or contingencies.

Several countries are currently interested in upgrading their tanker fleet. They include Japan (assuming amendments to their Constitution forbidding force projection are approved), the United Kingdom, Italy, Germany, and NATO itself. (Jane's, 2001-02) Several of these countries have not waited for the United States and have already moved forward in procuring new tankers. Italy and Japan have entered into contracts with Boeing for a tanker version of the Boeing 767. The 767 was chosen over a tanker version of the Airbus 310, labeled the Multi-Role Tanker Transport (MRTT) which was offered by Airbus in the competition. Each country cites Boeing's experience in developing tanker technology as the major factor in their decision. Were the United States to pick a platform and begin development soon, many of the other countries would probably follow suit, assuming the funding was available. The United Kingdom has also expressed an interest in Boeing's 767 tanker, but are also looking at an Airbus version, mostly due to the European Union loyalty factor encouraging those nations to support the

Airbus dominated European consortium. Needless to say there is a worldwide market for a future tanker aircraft although the major customer would be the US military.

2.5 Current Industry Concepts

Since we've established that there is a market for tanker aircraft, we need to look at what the aircraft industry is currently working on. Since the original plan from the US Air Force was to upgrade the KC-135, Boeing is currently working on upgrading all the KC-135s in the military. They have established new navigational, electronic and structural requirements and developed systems to attempt to bring the aircraft's systems into compliance to avoid restrictions on the aircraft from air traffic control authorities. At the same time Boeing has developed a tanker modification for its Boeing 767 aircraft and are touting it as the future replacement for the KC-135s. As I mentioned Japan and Italy have already purchased this aircraft for their aerial refueling needs. Airbus has developed a tanker/transport version of their A330. They are marketing it as a dual role aircraft to the European countries that cannot afford to buy a fleet of aircraft purely for aerial refueling. Most of these countries use their tankers only occasionally, and it must be able to fulfill another role, such as airlift, before their purchase can be economically feasible. Boeing and Lockheed are also developing a concept tanker aircraft in case the United States continues to refurbish its KC-135 fleet and elects to buy a purely military version tanker in the future. Boeing is focusing its efforts on a Blended Wing Body (BWB) design. This concept basically is a fuselage with an elliptical cross-section blended into a flying wing. A modular design would allow widespread part sharing between aircraft of varied size and capabilities. This concept holds tremendous potential as an airlifter/airliner but also holds potential as a multi-role tanker/transport or even a bomber.

Lockheed Martin Aeronautics is focusing its development efforts on the box wing concept. This aircraft would have the traditional cylindrical fuselage. The top wing design is swept forward and joined at the tips to a bottom aft swept wing. This aircraft should also support a modular design and could conceivably perform a multitude of military missions with its different configurations. (Rollins, 2001: 15) Another avenue for exploration in the tanker industry is an Alexandria, Virginia based company called Omega Air. They are an aircraft modification/maintenance company that has recently begun purchasing Boeing 707 and DC-10 aircraft. Their strategy is to offer aerial refueling on per hour contract basis to the governments of the world. They are already in negotiations with the United Kingdom and have just recently finished a test program with the United States Navy. They claim to be able to fill the void between current military capabilities and certain contingency ops, which the US tanker force has trouble supporting. They charge a per-hour rate and their pilots will be trained to the same standards as military tanker pilots. They currently have only a couple of Boeing 707's modified for tanker ops and are exploring the market before modifying their remaining fleet. They also currently use a hose and drogue refueling system. Future modifications to include the boom system used by the US Air Force will depend on the financial viability and potential usage by the Air Force. (Matthews, 2002)

2.6 Acquisition Methods

This is a subject under much debate recently. Most Air Force acquisitions follow the military model of providing requirements to industry and taking bids before finally choosing a contractor to provide the product or service. September 11 has increased the urgency of providing the military with the means to thwart the terrorist threat. Congress

and the President are united in their goal of improving our security and providing the military with the tools needed to battle terrorist organizations around the world. This has reopened the subject of a new tanker force and pushed it to the forefront of the military acquisitions wish list. But what is the best method to acquire these new aircraft if they are purchased? How can we possibly afford to buy 600 tanker aircraft while at the same time continue the acquisition of current programs like the C-17, the Joint Strike Fighter and the F-22? A novel idea has been proposed. Boeing has offered 100 767's directly from their factory, with tanker modifications, to the Air Force as a leased product. This provides the military the opportunity to significantly move up their timetable for acquisition because they can use a different pot of money (operational and maintenance - O&M) for leases than they do for purchases. There are some legal sticking points with a lease and Congress is currently debating the finer points of the law. There are several proposals out there including many combinations of different options where new tankers supplement a smaller refurbished KC-135 and KC-10 fleet.

Chapter 3 – Methodology

3.1 Overview

Basic Research Question: *“What future capabilities will be necessary in tomorrow’s Air Force tanker to meet the sophisticated and complicated needs of the military into the 21st century?”*

In the basic sense, the research method combines several areas. They include: literature reviews, expert interviews, and case studies. The basic research question is predicated on a relationship between several constructs: commercial demand, military demand, acquisition approach and timeline, industry research and development, capabilities requirement, and valid acquisition alternatives. The theory is that if we can combine the military requirements (capabilities) with current or future commercial technology we can produce a product that would be beneficial to the military community and also the commercial market. If the government isn’t able to purchase a new platform at the present time this research will show some alternative methods to maintain capability until such time as there is more funding available. This research work is organized around a subset of questions supporting the overall goal of making recommendations to the Air Force about how to maintain and/or improve upon its core competency of rapid global mobility from an aerial refueling (force projection) perspective.

3.2 Guiding Research Questions

1. What are some estimates for the military’s aerial refueling needs?
2. What is the current market for tanker aircraft and what is the expected growth?
3. What are the options for tanker airlift procurement?
4. What is the industry working on now?
5. Can the acquisition of a new tanker be restructured to include the hiring of commercially operated tankers?
6. What are the required capabilities of the Air Force’s next generation tanker?

3.3 Technique For Answering Questions

What are some estimates for the military's aerial refueling needs?

The problems of today's aerial refueling capability are a known fact and are currently a hot topic. Thus, this study is not trying to prove that there is a shortage or that the current KC-135s are having problems. The literature review of open source documentation has collaborated this opinion and the effort of this paper.

What is the current market for tanker aircraft and what is the expected growth?

This question is answered by reviewing books, magazine articles, professional transportation journals and expert interviews. I have studied sources from within the industry as well as external to the issue to insure a balanced picture. I maintain that the synthesis of these opinions will portray the current and future commercial market and its expected growth potential.

What are the options for current tanker procurement?

Historically, tankers have been derivatives of current commercial airline platforms that have been modified for the aerial refueling mission. Through my research I will show that there are several options to consider. There is the continued option of modifying a current commercial airliner derivative and also options for upgrading the current KC-135 fleet for continued service with a future tanker to be developed. Whether this future tanker should be a commercial off-the-shelf platform, or a completely new airframe developed from the ground up to fulfill the capabilities required by the Air Force of the future, is a topic of debate. These options must also consider the recently introduced options of a short-term lease option and also the possibility of contracting a portion of the military's aerial refueling needs from a civilian contractor.

What is the industry working on right now?

The research for this information was a compilation of a search of current literature (sources mentioned above) as well as interviews/conversations with Omega Air and Boeing officials. All sources were helpful and provided valuable insights into their perspectives of the subject.

Can the acquisition of a new tanker be restructured to include contracting commercially operated tankers?

Contract aerial refueling is being considered by several countries as a way to provide a low cost way to buy excess capability. My sources are mainly current literature as well as an interview with the president of Omega Air, Inc., Mr. Gale Matthews. There is information available due to the highly public debate about the proposed Boeing tanker lease deal and Congress' attempts to find other options.

What are the required capabilities of the Air Force's next generation tanker?

While I consider this the most important question to be answered before any acquisition effort there is only slightly more information on the subject than there is about the lease option currently being considered. I found significant sources in the current military literature about the proposed "SMART" tanker that is the Air Force vision of what a tanker may be used for in the future. In fact, much effort is already being expended on researching these capabilities. The majority of my information on what would be expected from a commercial airline platform purchase is detailed in the draft version of "Commercial Derivative Air Refueling Aircraft Program" Document developed by Headquarters, Air Mobility Command. This very detailed document was very informative on the specific AMC requirements for a commercial tanker if acquired in the near term.

Drawing Conclusions and Making Recommendations

The result of answering these questions should provide a clear understanding of how to fulfill the Air Force's future tanker requirements. The concept of the multi-role military aircraft is not new but the concept is going even further with the hopes of lower costs, greater efficiency and even greater effectiveness. The conclusions of this report should combine requirements, capabilities and simple economics to provide a solution that will provide a robust aerial refueling capability that is severely needed in our future Air Force.

How does this research improve upon previous research efforts?

Much has been written on how and what to acquire to fix the "tanker" problem. Debate has raged on whether to lease or purchase a new aircraft, fix the KC-135 to extend the life for 20 to 40 more years, or even contract our tanker assets to reduce the expense of maintaining crews, aircraft and required infrastructure. I researched the same subjects but I believe my efforts to highlight future requirements/capabilities improves upon earlier projects. You cannot decide on an acquisition course unless you show what the aircraft will be required to do. With this knowledge an informed, educated decision can be made.

Chapter 4 – Findings

4.1 Replacement/Acquisition Issues

With the amount of focus directed at the tanker issues in today's military, it's hard to understand how anyone could still harbor the idea that our refueling force is healthy. Although, not currently healthy, the question is "How do we fix it?" We not only need to look at how to fix the problems but what capabilities are required in tomorrow's refueling force that we may not necessarily have today. Currently, the Air Force has a large faction of individuals who believe the KC-135 is on the road to recovery and its useful life can be extended for 20 to 40 more years. Recently, this number has dwindled from previous numbers due to the high tasking of the aircraft by Operation Enduring Freedom. But what is the best option for replacement? Do we replace all of the KC-135's or do we only replace a portion of them, i.e., the older E models? These are not the only questions that need answers before an informed and educated list of options can be developed to produce a solution.

4.1.1 Number of Engines

Were the Air Force to replace the KC-135 with a modern commercial off-the-shelf civilian airliner, an immediate issue would be the number of engines on the airframe. With only two engines reliability may become a more important consideration than before. An engine failure on the 4-engine KC-135R is arguably a less-serious matter than an engine failure on the 2-engine 767 – especially on long transoceanic missions, or over rugged terrain or hostile territory. Currently the only Boeing aircraft with more than 2 engines is a version of the 747 and the C-17 – both of which are much larger and significantly more expensive aircraft to acquire and operate. (Harris, 2001) The primary

need of the airline industry is to provide a certain amount of space in which to carry passengers at a minimum cost-per-seat-mile. These economic imperatives, along with the high thrust and reliability of modern engines, have lead to the dominations of the twin-engine configuration for current transport aircraft. But even with this high reliability and thrust rate, civilian and military aircraft takeoff power is still planned assuming the loss of an engine during takeoff roll. After an engine loss, the aircraft is still required to continue the takeoff and maintain a positive climb gradient. Climb gradient is a function of thrust to weight ratio. The takeoff climb requirement is more severe for a twin-engine aircraft, since they must continue with only 50 percent of the original thrust. This limits the amount of payload weight for a twin-engine aircraft more severely than it does a 3 or 4 engine aircraft. Twin-engine aircraft have a payload weight fraction of maximum takeoff gross weight of about 0.50 whereas the comparable number for a KC-135 is 0.62. This ratio is the ability to lift fuel into the air and deliver it to receiver aircraft, and is the measure of efficiency for a tanker aircraft. There is no current aircraft of comparable size on the market that can do the KC-135 mission as efficiently as the KC-135. (Fedors, 2001: 1)

4.1.2 Number to Buy

Another basic consideration is how many aircraft do you replace and at what ratio? Regardless of the replacement schedule the aerial refueling requirements haven't changed. The 2002 Air Mobility Command Strategic Plan showed no change in the aerial refueling requirements for the Air Force. In other words, whether the KC-135s are replaced or not, the same amount of fuel must be capable of being delivered. There are studies saying that a one-for-one replacement is necessary regardless of the aircraft the

KC-135 is replaced with. What factor is most important to compare? Should the same number of booms be available regardless of the number of aircraft? Should total aerial refueling capacity be the issue? This is still a subject of debate but most recent studies point to total aerial refueling capacity as the overriding issue of importance. A recent 452nd Flight Test Squadron study created a comparison table for current Boeing aircraft in several areas including operating cost and number required (based on refueling capacity). (Fedors, 2001: 3)

Table 5. Aircraft Comparison

Data Subject	KC-135R	767-300F	757-200F	737-900
Max Takeoff Gross Wt (MTOW), 1000 lbs	322.5	412	255	174
Operating Empty Weight, 1000 lbs	122.5	188	112	93
Payload, 1000 lbs	200	224	143	81
Payload, weight fraction of MTOW	0.62	0.54	0.56	0.46
Payload, fraction of KC-135R	1	1.12	0.71	0.4
Operating cost/hour	\$3,225	\$4,120	\$2,550	\$1,740
Operating cost/hour per 1000 lbs of fuel	\$16.12	\$18.40	\$17.83	\$21.48
Operating cost/hour per boom	\$3,225	\$4,120	\$2,550	\$1,740
Acquisition cost/aircraft (millions)	15	111	96	55
Number of aircraft needed (total fuel cap.)	550	550	775	1375
Cost to upgrade/replace 550 aircraft (billions)	8.25	61	74.3	75.6

(Fedors, 2001)

You can see from the table that the 767 is the only aircraft which is comparable in total fuel capacity to the KC-135. The 757 and the 737 would require the purchase of additional airframes to provide the same capacity as 550 KC-135s or 767s. Another advantage of the 767 is that the total number of “booms in the air” would be the same. There would be additional problems with scheduling if a larger capacity aircraft is purchased resulting in fewer total aircraft. During a contingency there is considerably more missions to fill than there are aircraft available. The resulting shortage is the primary reason for the over tasking of current tanker aircrews. A recent Air Force Times

article cites a recent Office of Management and Budget Report that says replacing the KC-135Es would not solve, and may exacerbate, the tanker problem. The report claims that although the 767 holds more fuel than the KC-135E, 100 767s don't carry as much as 126 KC-135E Stratotankers, resulting in about 103 million fewer pounds of fuel.

(Castellon, 2002)

4.1.3 Infrastructure Costs

Considering the Air Force is probably looking for a larger, extended range aircraft they cannot ignore possible infrastructure costs. For example, a recent GAO report claims that building new hangars for the 767s alone will cost \$1.7 billion dollars compared with \$3.7 billion to upgrade and re-engine all the KC-135Es to R model standards. (Castellon, 2002) But, the GAO report doesn't take into account further expenses for an aging aircraft compared to the improved efficiency of a newer, more modern, airframe. An in-depth cost analysis is impractical for the focus of this paper but infrastructure costs are definitely an important factor to consider. Consider that hangars are not the only possible costs. The Air Force must analyze spare parts procurement and storage facilities, maintenance facilities, training for not only crews but also repair technicians and aerial port workers, and a myriad of other factors. All new aircraft have additional expenditures other than simply acquiring the airframe, but these costs must be weighed against the other possible savings created by the purchase. For example, the same Air Force Times article points out that there would be approximately \$23 million per year in savings in operation and maintenance costs if the KC-135Es were replaced. (Castellon, 2002)

4.1.4 Noise Reduction

Although most people don't even consider the problem of aircraft noise it is quickly becoming a subject that the Air Force cannot ignore. More and more restrictions are being put on aircraft engine noise. Most metropolitan areas, especially those in Europe associated with densely traveled airports and military fields, are enacting noise level restrictions on certain older, high decibel aircraft. The old KC-135 models are unable to meet these restrictions and are increasingly running into host nation complaints about their noise generation. Although this problem is alleviated somewhat in the KC-135R model it still doesn't equal the levels of quietness achieved by modern aircraft like the Airbus 330 and Boeing 767. Consider that the noise level of a 767 taking off from a 1.5 mile runway is about the same as the average street corner traffic noise. (Boeing, 2002)

4.1.5 Commercial/Foreign Demand

Both commercial derivatives currently being considered are popular on the commercial market. The Boeing 767 has been around for a couple of decades and is well established throughout the airline industry. Recent events have significantly hurt the civilian aircraft industry. During times of civilian economic downturn the airline industry focuses on military business to weather the economy. Airbus has steadily increased its market share in the commercial airline industry over the years and is pushing hard to get a foothold in the military aircraft industry. Airbus is attacking in the area where they have the best chance of initial success, commercial derivatives modified for tanker/airlift operations by their partner in the United States – Raytheon. Airbus has developed a Multi-Role Tanker Transport (MRTT) to fill this role and it is based on the

A310 aircraft. It was developed to meet British, Canadian, German, Japanese and Italian requirements for a new tanker. (DefenseDaily, 1999a) Due to the small number these countries will purchase, a dual role airlift capability is required for economic reasons.

Boeing is touting its 767 version with an updated modern boom design as well as hose and drogue capability. Currently Japan and Italy have awarded their contract to Boeing and its 767 tanker. Japan chose the 767 over the A310 offered by Airbus. Japan is believed to have chosen the 767 because of their relationship with Boeing developed when Japan purchased four 767s modified for Airborne Warning and Control System (AWACS) planes. (AP, 2001) Italy announced Boeing as the winner in its tanker competition in July 2001. Italy reportedly decided that Boeing's 767 offered a better combination of performance and cost. Italy has a track record with Boeing, who provided their current tanker fleet of converted 707s. The ability of the 767 to leave the main cabin free for cargo and still accomplish the refueling mission was also a deciding factor. (Wallace, 2001)

Britain is currently investigating a study called Future Strategic Tanker program, which has some unique aspects. They propose to lease tankers (either Airbus or Boeing version) from a civilian contractor. The contractor will provide the tanker and give the British government priority for use in both tanker and airlift roles. When not needed by the military, the planes will be available for contracting with civilian cargo companies or even foreign militaries for aerial refueling or cargo operations. The major problem is economics. Britain has not been able to get the investment needed to purchase this capability. (Kershaw, 2001) (Hewish, 2000: 1,2) Currently Germany and Canada are also researching a competition between Airbus' MRTT and Boeing's 767. (Braybrook, 1997)

It is obvious that in addition to the commercial interest in the aircrafts there is considerable military application in the tanker/transport field.

4.1.6 Boeing 767

Boeing 767 Tanker (Artist Rendition)



Since September 11, the aircraft industry has been feeling the pinch of a downturn in the economy, especially the travel industry. This has subsequently presented the US government an opportunity to purchase/lease 767s directly from the production line and modified for tanker operations, all at a supposedly “bargain” price. Air Force Secretary, Jim Roche, in a recent interview, said “This is not a bail out, but taking advantage of a buyer’s market. This can be a win-win. Boeing needs business, and we need airplanes. Does this preclude competition in the future? Absolutely not.” (Muradian, 2001) That being said, with Boeing’s past experience with tanker aircraft they have always been the

frontrunner in the competition to replace the KC-135. Let's look at some of the specifics of the 767 and Boeing.

The initial advantage that comes to mind is the experience Boeing has with tanker aircraft production. Most of the U.S. tanker aircraft are Boeing products and Boeing is the sole provider of the flying boom system used on modern tanker aircraft. In fact they are the only company that has ever built a flying boom system. The 767 has already been purchased as a tanker by the Italian and Japanese Air Force. It beat out the Airbus MRTT in both competitions mainly due to Boeing's experience with aerial refueling aircraft. Look for Britain, Canada, Australia and even Singapore to be evaluating the 767 in the near future. The 767 could be used in several different military missions like the Joint STARS, aero-medical, AWACS, communications, and electronic surveillance.

(Muradian, 2001) In fact an aero-medical modification is already available for the 767. It was developed for 767s that are in today's Civil Reserve Air Fleet (CRAF). Boeing says the 767 is in plentiful supply, and is well supported into the next decade by a worldwide support infrastructure. (Harris, 2001) There are currently over 800 767s in airline and military service around the globe, so this doesn't seem to be an idle statement.

If the 767-200 version is used the tanker "fuel offload" capacity is 100,000 pounds – about 20% more than the KC-135's. It could cruise at Mach 0.8 and would have an estimated range of about 4000 miles. These numbers would increase were the military opt to purchase a freighter or extended range version. KC-135s cruise at the same speed and can reach about 5000 to 6300 miles. Four versions of the 767 tanker are currently envisioned by Boeing: a passenger version, a freighter version, a "convertible" version (changeable between cargo and passenger use), and a "combi" version

incorporating both cargo and passengers simultaneously. Boeing is no stranger to major aircraft modifications. They carried out the KC-135R re-engining program and even turned a conventional 747 into Air Force One. (Harris, 2001) A very significant advantage of the 767 is its operational flexibility. It has the capacity to carry 20 pallets of cargo, 14 more than a KC-135. (Sirak, 2001) The 767 will be equipped with a Boeing developed boom as well as a hose and drogue system and will be compatible with European and NATO forces. It also claims to be compliant with the strictest noise and environmental standards. (Boeing, 2001) Additionally, the fact that Boeing is an American company has strong weight in Congress. It will be difficult to imagine Congress voting for the purchase of a foreign aircraft, unless the price is significantly better or the technology is unavailable in the United States. (Nick Jonson and Marc Selinger, 2002) In fact, in a March 2002 letter to Secretary Roche, Representative Todd Tiahrt (R-Kansas), a member of the House Appropriations Defense Subcommittee who has urged the Air Force to “buy American,” wrote that over 88 percent of the dollar content of the 767 is American. Secretary Roche says that both aircraft, the 767 and the Airbus A330 are “world” airplanes and contain portions from the United States and overseas. (Marc Selinger, 2002)

There are some disadvantages to the 767. First is the cost. According to Boeing, 767s cost between: about \$100 million and \$112 million for a 767-200 Extended Range (ER) aircraft; about \$114.5 million and \$127.5 million for a 767-300 ER; about \$121.5 million and \$134 million for 767-300 Freighter; and between \$125.5 million and \$138.5 million for a 767-400 ER. To date it is not clear which version appeals the most to the Air Force. Additionally, there will be a significant cost of modifying the aircraft into the

tanker version. This has been estimated to cost between \$20 million to \$35 million per plane depending on the number purchased. (Muradian, 2001) Also, many critics point to the technology of the 767 as antiquated. They claim the airframe is old technology and the Air Force should focus on a more recently developed airframe such as the Airbus A330 or the Boeing 777. Additionally, members of Congress point to the added expense of infrastructure costs, such as hangars and basing inadequacies – these critics, most notably, Senator John McCain consider a lease of 767s as a waste of taxpayer money.

4.1.7 Airbus A330



Airbus MRTT

Airbus' offer is a modified version of the A330-200 passenger jet equipped with various refueling systems that could refuel Air Force and Navy planes, which could include a boom of designed by EADS – an 80 percent shareholder of Airbus. An initial proposal to the Japanese using the A310 MRTT included wing-mounted refueling pods. Optional features included military avionics and defensive aids, ability to receive fuel, and several different fuel-transfer options utilizing a center-line hose, a multi-point hose

system or a flying boom system. The aircraft can carry more than 170,000 pounds of fuel with a range of over 5000 miles. The modification to the MRTT configuration, conducted by Raytheon involves the addition of a cargo door, additional center-line tanks, external lighting, video monitoring and an operating console. The A330 can also be configured for aeromedical evacuation, palletized cargo delivery, passenger movement up to 279 people, or a “combi” configuration incorporating a percentage of each mission configuration. (DefenseDaily, 1999b) Airbus has an advantage over Boeing in newer aircraft avionics and electronics due to their high investment in technology systems for their civilian airliners. This would be Airbus’ best advantage in the tanker aircraft competition.

There are several disadvantages to purchasing an Airbus aircraft. First, and most contentious, is whether the United States can purchase from a foreign company a product when a comparable product is made in the U.S., especially during slower economic times. As I mentioned earlier both aircraft will have significant “world-wide” participation in the development and construction, but Boeing’s 767 will have over 80 percent American company development/construction. When asked what the Airbus aircraft’s American percentage would be, Secretary Roche said “it was much less than that” 80 percent. Another disadvantage is the perception that Airbus will significantly lag Boeing in boom technology and development. Critics claim it would take at least five years before Airbus can field a first generation flying boom, barring a partnership with a company or country that can provide that technology, like Israel Aircraft Industries. Another disadvantage is the larger size of the A330, which was the first choice of Airbus to compete in the American tanker competition. The infrastructure costs would be even

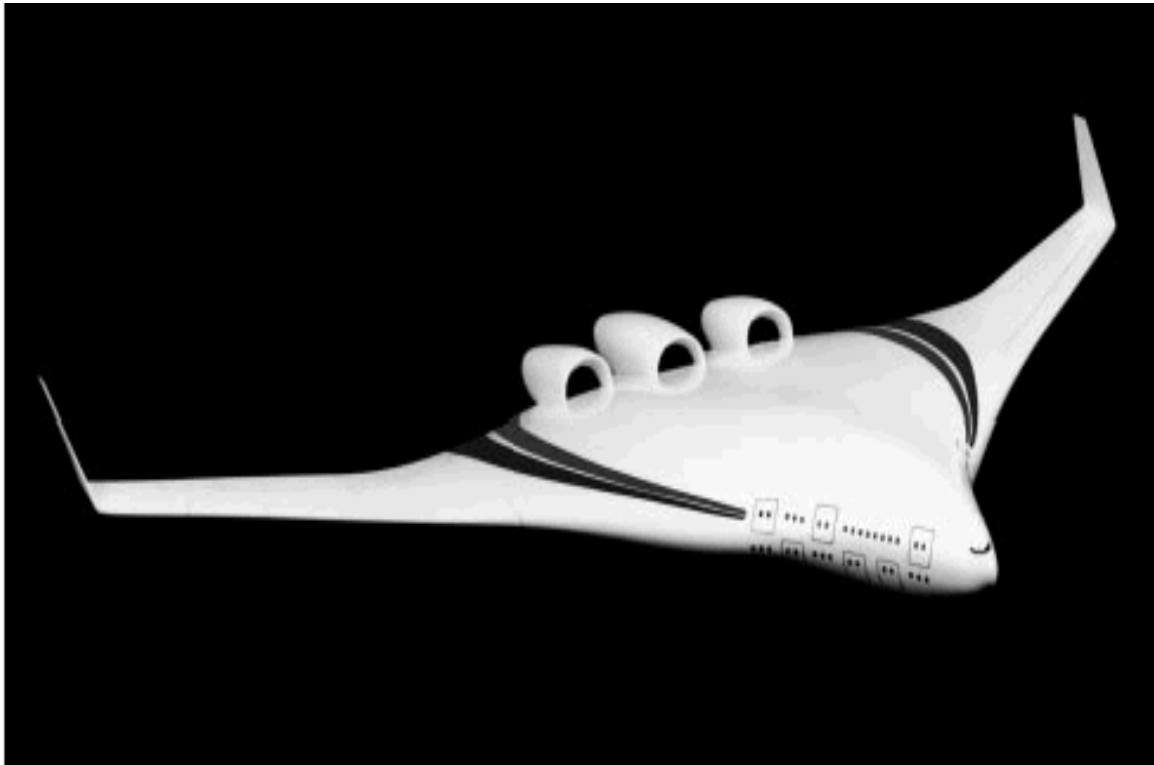
higher than for the 767 because the A330 takes up even more space than the 767 or the A310. Airbus did not rule out offering the A310, offered previously as the MRTT to European countries, at a later date. Airbus claimed confusion and the lack of a formal request for a bid as the reasons for not having multiple aircraft offers on the table. Many Air Force officials indicate they would like some larger tankers (A330/340 with better cargo/passenger capability along with some smaller, pure tankers (A320) that maximize refueling capacity but take up less ramp space. The bottom line is that Airbus is at a disadvantage in every area except for the specific aircraft technology, which is definitely equal to the 767 in the A310's case and probably better in the A330 or newer airframe. The lack of military contract experience by Airbus is a serious disadvantage but does not preclude them from competing now and especially in the future. (Fulghum, 2002c)

4.1.8 KC-X

There is also the option of upgrading the KC-135s and working with industry using the normal acquisition process to develop a future military-only tanker aircraft. This aircraft would not be a commercial derivative and would be built to military specifications. Military aircraft are not used in the same manner as commercial airliners and many congressmen and military leaders believe an aircraft designed specifically for the harsh reality of military usage is essential. Both Boeing and Lockheed are currently working on an advanced design tanker aircraft that they believe could have a dual or even multiple role mission. Lockheed Martin's advanced design team in Georgia believes a modified airliner would not be the best solution because it is large, heavy and tied to long, well-prepared runways. They also claim that buying a commercial airliner may not be the least expensive option – the 767 is showing signs of reaching the end of its sales

life. The Air Force is already rapidly becoming the only major operator of the DC-10/KC-10 and are running into the associated supply and parts acquisition problems. Lockheed advocates a Joint Strike Fighter (JSF) type prognostics system – which detect failures before they happen – and open architectures to produce a design which will reduce life-cycle costs.(Sweetman, 2001) Lockheed and Boeing are both going in different directions in their development of the future KC-X military tanker. Boeing is leaning more toward the blended wing technology and Lockheed is focusing on a box wing approach.

4.1.8.1 Blended Wing Body Aircraft

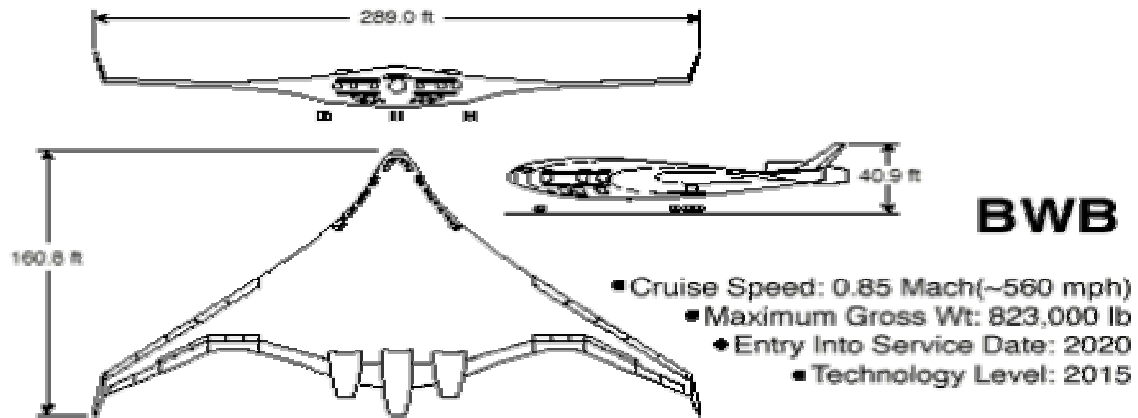


Blended Wing Body (Artist Rendering)

The Blended Wing Body (BWB) concept aircraft combines the wings and fuselage into an aircraft requiring no tail. The BWB has possible applications as a

commercial airliner, cargo transport, aerial refueling tanker or even a bomber. The BWB has a thick, airfoil-shaped fuselage section which combines with the wings to maximize efficiency and capability. Integrating the engines, wings, and body into one single, large lifting surface derives this efficiency. Potential benefits include very long range, large payload, and reduced acquisition costs. Operational costs should also be reduced because there are fewer parts and assemblies with the elimination of the empennage. This technology is an extension of the technology developed for the B-2 and other flying wing aircraft. (NASA, 1997) Boeing believes the BWB, if developed, will be a series of aircraft with common components such as cockpit, power plants and wing tips that can serve in multiple roles and missions. As a tanker the 3-bay BWB could carry approximately 110,000 pounds of fuel or cargo. It could easily be designed with a twin boom configuration with reduced wingtip turbulence problems due to its unique design. This would be a unique advantage for performing fighter drags across the oceans and deliver the same refueling/cargo capacity with fewer airplanes. The bigger 7-bay BWB could conceivably offload over 500,000 pounds of fuel. (Rollins, 2001: 42) At 289 feet wide, it is 67 feet wider than the 747. Some existing runways and taxiways will not be able to accommodate the BWB. Parking and infrastructure concerns would be limiting factors at some airports. Another fact to consider is that to meet stability, control, and ride quality requirements the BWB will require sophisticated flight control technology like the F-117, B-2 and the B-1. Also with such a radical design the development costs and associated risks will be extensive, much more so than a conventional aircraft. Very large return on investment would be required to motivate the high developmental dollars

that would be required to move beyond the current, small effort at development. (BW-98, 2000)



Blended Wing Dimensions and Facts (WebArticle, 1999)

4.1.8.2 Box Wing Aircraft



Box Wing Aircraft (Artist Rendition)

Lockheed Martin's entry into the joined wing technology is the box wing aircraft. Traditional joined wing aircraft designs have two sets of wings, on the same plane, which are alternately swept back from a mounting on the forward fuselage and swept forward

from the a mounting on the rear fuselage. They are then joined in the center and look like a normal single wing aircraft from the nose of the aircraft and like a diamond from above. Lockheed's model has the same design except the two sets of wings are built in different planes and joined with vertical wing tips. This closed rectangle is predicted to produce the least amount of drag for a given wing span and area. (Carroll, 1974)

Lockheed envisions this box wing aircraft flying as a passenger airline, airlifter, aerial refueling, and even a super freighter. Like the BWB, each version would benefit from making extensive use of interchangeable parts and systems. Like the BWB, the box wing aircraft should provide multi-point or multi-boom configurations. The box-wing aircraft should also be a capable dual cargo/tanker like the BWB and the KC-10 but with the added advantage of roll-on roll-off capability for vehicles, equipment and ISO containers. Even after flying over 4600 miles it will still be capable of offloading more fuel than a KC-135. ("Market Report - Strategic Airlifters," 2000) Lockheed has also studied a box wing aircraft about the size of the KC-135 that could carry multiple booms and drogues to lessen refueling time for fighters. Lockheed has flown a scale model of the aircraft and they say it will be able to carry 120,000 pounds of cargo or 200,000 pounds of fuel for 1,000 miles – or a lesser combination of the two. (Wolfe, 2000) There are no significant technological hurdles to overcome with this concept. The only problem would be Lockheed's mediocre performance in the large aircraft production arena. Other than the C-130 variations they have little recent experience in this area. Opponents believe the C-130 line wouldn't have continued without congressional authorizations far in excess of military request. Without this governmental support Lockheed may get out of the large aircraft making business that would leave a U.S. monopoly for Boeing.

4.1.9 Omega Air

A tanker option that has not received much attention is contract or “fee for hire” tankers. Omega Air is an Alexandria, VA based international company that has historically specialized in aircraft sales, service and parts. They also have been exploring the market for commercial aerial refueling tankers for hire. They use modified Boeing 707 aircraft that have a hose and drogue system commonly used by the Navy and NATO aircraft. According to Omega Air’s president, Mr. Gale Matthews, “There are no known equipment or technical obstacles to preclude program development. We will not compete with the US Air Force but will supplement requirements where needed.” They will be available during test exercises or contingencies to provide an alternative, responsive refueling capability. Omega Air recently purchased the Japan Airlines’ fleet of twenty DC10-40 for conversion into a refueling fleet. According to the GAO report NSIAD-96-160, the cost of maintaining and operating a refueling fleet is prohibitive. Costs can exceed \$10,000 per flight hour. Most nations cannot afford this although the demand for aerial refueling capability is rising. The aircraft could fulfill a dual cargo/aerial refueling role and could be leased by the hour. (Herod, 2002) Mr. Matthews quoted a price of approximately \$6,000 per hour for the 707 and \$8,500 for the DC-10. By comparison, the General Accounting Office says the per-flight hour cost for an Air Force KC-135 is projected to be \$10,761. He also claimed his pilots would be trained on the same procedures that the military requires of their own tanker aircrews. When asked about possible use in a combat arena, he claimed that was already being done, “Civilian aircraft are flying into Afghanistan as we speak and we see no problems with providing the same level of aerial refueling expertise as a military aircraft.” (Matthews, 2002)

In a recent test of Omega Air during a Navy exercise, the results were called a resounding success after the Omega Air 707 had flown 248 hours and refueled 825 Navy aircraft, including F-14s, F-18s, EA-6Bs and S-3s. Over this time the 707 pumped 2.5 million pounds of jet fuel. “Their mission rate to date has been 100 percent,” says Teri Boswell, assistant deputy program manager for commercial services at NAVAIR. “Omega’s been excellent and the fleet’s very, very happy.” Boswell went on to say the sortie rate for their battle group increased 50 percent over previous exercises because of the Omega tanker. Essentially, this provided the Navy with an alternative to Air Force tankers, which can be pulled away for other missions. (Laurenzo, 2002)

The Omega pilot program for the Navy has been so successful, Senator John McCain (R-Arizona) is curious as to why the Air Force refuses to consider civilian refueling as an alternative to a controversial 767 lease-deal being discussed. (Laurenzo, 2002) The cost advantages are obvious and the question of expertise could be tested by the Air Force. Disadvantages include possible aircraft insurance problems although CRAF contracts have been dealing with this problem for years and should have no problem working out a solution.

4.2 Future Capabilities

Having covered some important issues about the Air Force tanker’s future we need to enter the realm of required capabilities. What should our next aircraft or system be able to accomplish for us? The research was replete with references to “multi-role” and “smart” tankers and/or military aircraft. But when it gets down to writing our future requirements, what will or should they be? Should we use “spiral development” or in other words buying an aircraft platform developing its mission during the aircraft

production to enhance capability. The concept of the “smart” tanker is related to the spiral development concept. But first, let's look at the basic mission, a tanker aircraft and the requirement for a dual role as a cargo aircraft.

4.2.1 Multi-Role (Tanker/Transport)

Keep in mind the quote from Secretary Roche, “We will never buy another single role aircraft again,” Why have I mentioned this again and again? Because when you buy 500+ aircraft it is only smart to acquire a platform that can be used for a myriad of other missions. Since tankers are controlled by Air Mobility Command (AMC), and AMC's other major mission is cargo movement, why would you buy an aircraft which can't at least provide some degree of cargo hauling. One important mission of tankers is something called the “fighter drag,” which is escorting a group of fighters from point A to point B and refueling them along the way. Usually this mission requires the tanker to haul some amount of supplies, spare parts, personnel, and/or equipment for the fighter aircraft's support. This is especially important during the deployment phase when airlift requirements are highest. Therefore the next generation tanker must have some degree of cargo hauling capability, and preferably more than the meager amount provided by the KC-135.

The draft version of the CDARA program spells out the cargo capability requirements of a commercial derivative aircraft if the Air Force purchased or leased one. The aircraft must have a configuration capable of seating a minimum of 70 passengers and ten crewmembers as well as carry ten 463L air cargo pallets. When configured for all cargo it should be able to carry nineteen 463L pallets plus crew or 190 passengers plus crew for the all passenger configuration. Additionally, a powered door that permits 463L

pallet access on the wide dimension or capability to load on short side and rotate and line up inside is required. (AMC/XPR, 2002: 14,15) I mentioned before a possible aero-medical role, especially if the 767 was chosen. The CDARA document also calls for specific ability to configure for up to 50 patients total and 5 additional aero-medical crewmembers. (AMC/XPR, 2002: 22) Both the 767 and the A310/330 have significant cargo ability. For example, the 767 has the capacity to carry 20 pallets of cargo (A310 is slightly less, A330 is slightly more), which is 14 more than the KC-135, and an aero-medical modification is already available for use. (Sirak, 2001)

4.2.2 Boom versus Drogue/Multi-Point Refueling/Receiver Capability

The Air Force has used the boom aerial refueling system for most jet aircraft since the advent of Strategic Air Command. I've already covered the reasons for this, mostly because of the higher refueling rate for the boom versus the drogue system. Still, the majority of Europe and NATO's aircraft used the hose and drogue system due to the lower cost and the fact that they do not require the ability to cover such extreme distances as the United States. The United States Navy also prefer the hose and drogue system for their fighter and electronic warfare aircraft. You can guarantee that any future tanker aircraft will be required to efficiently operate under both boom and hose/drogue operations. During Operation Enduring Freedom the integration of NATO forces has highlighted the requirement for NATO compatibility in our tanker and other military assets. In fact, the CDARA Draft Document calls for a permanently installed air refueling boom and a permanently installed centerline hose and drogue refueling system. Furthermore, the aircraft must be able to use both (not simultaneously) boom and drogue refueling systems, day or night, on the same flight, offloading all available fuel with no

degradation to offload rate throughout the range of tanker fuel loads. The CDARA also requires the capability of boom and drogue air refueling of all current equipped receivers identified in Air Force Technical Orders as well as the F-22 and Joint Strike Fighter (JSF). For hose and drogue operations a portion of the aircraft must be able to simultaneously refuel two receivers, and for those not modified for this capability, a second drogue system for redundancy is desired. (AMC/XPR, 2002: 20,21)

While not specifically mentioned in the CDARA draft, there has been some mention of multiple wingtip boom requirements. A recent flight test shows that multiple booms are impractical for large aircraft. For large aircraft, half of the receiver's wing is in the downwash of the tanker's wing, while the other wing of the receiver is in relatively undisturbed air. This creates a very strong rolling tendency by the receiver towards the tanker. Stabilization behind another aircraft's wingtip is the most difficult position to hold in the entire tanker flow field and usually requires full lateral control deflection and use of sideslip. During turns the receiver must not only roll with the tanker but translate up and down as the wing rises or falls in the turn as well. This seems to preclude further requirements for wingtip booms and explains the CDARA's wingtip drogue system requirements. (Fedors, 2001: 2)

The Air Force's requirement for boom technology in its next tanker aircraft is believed to be a major factor in the Airbus A330 being eliminated from the competition with Boeing. Boeing is currently the only company with boom technology in use. They developed the flying boom technology at the request of the Air Force in the late 1940's. Airbus' claim they could easily develop a boom system compatible with current Air Force technology was met with skepticism. Critics of the EADS/Airbus initiative claim it

will take a minimum of 5 years for the company to develop first-generation boom system, while Boeing is already readying third and fourth generation refueling systems.

(Fulghum, 2002c)

4.2.3 Fuel Available for Offload

As I mentioned in the previous section fuel capacity is a primary focus of the acquisition team. For comparison, the primary competitor to the 767 is the Airbus 310. In the recent competition with Boeing for the Japanese tanker contract, Airbus claimed their MRTT would be able to carry more than 170,000 pounds of fuel, with a range of over 5000 miles. While the Boeing 767's payload of 224,000 pounds would be regulated by the takeoff weight fraction, due to having only two engines, the total payload would still be in excess of 200,000 pounds, depending on cargo requirements of the mission. (Fedors, 2001) Current Air Force tanker offload capability is portrayed in the following table extracted from Air Force Pamphlet 10-1403.

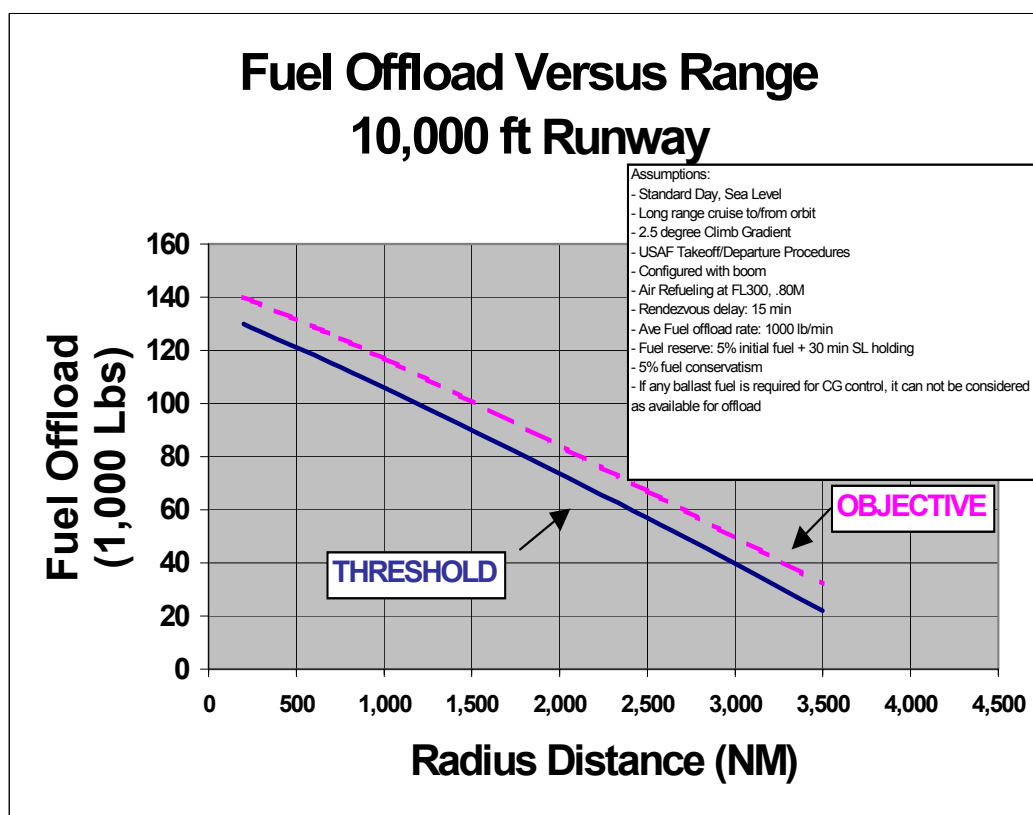
Table 6. Tanker Offload Capability

	(Lbs)		Max Offload (Based on Mission Radius)			
	T/O Gross Wt	T/O Fuel Load	500 NM	1000 NM	1500 NM	2500 NM
KC-135E	275,700	160,000	101,200	78,600	55,800	10,500
KC-135R	301,700	180,000	122,200	99,400	76,400	30,700
KC-10	587,000	327,000	233,500	195,200	156,000	78,700

Tanker Offload Capabilities (Brummett, 2002)

As you can see, the 767 has a fuel capacity greater than the KC-135R model and the Airbus 310 MRTT has approximately the same capacity as the KC-135 with its 170,000 pound limit. Now that we know our current fuel offload capabilities we need to know what will be required of our next tanker. The following graph is a depiction of the

required fuel offload based on range, originally shown in the draft version of the Commercial Derivative Air Refueling Aircraft Program (CDARA) Requirements Document. As you can see from this fuel offload requirements chart, the offload requirements are slightly higher than the KC-135 offload rates shown in the above charts.



For example, the KC-135R can deliver an offload of 99,400 pounds over a 1000-mile mission radius. The CDARA will require an offload capability of approximately 107,000 pounds as a threshold (minimum) with an objective (desired) of just under 120,000 pounds. (AMC/XPR, 2002: 41) Although this is a draft version of the CDARA it is obvious the Air Force is looking for greater capability than the KC-135 provides, leading us to believe they are looking for a larger, extended range civilian aircraft as the next tanker.

4.2.4 “Smart” Tanker

The SMART weapon concept is an intellectual progression from the platform-centric mindset of past Air Force acquisitions. What can we do with the platform? Experts are literally thinking “out of the box” in an attempt to squeeze every drop of capability out of each weapon system. Major General Daniel Leaf says, “We want to use SMART Tankers, F-16s, F-22s and Global Hawks (UAV) all in concert.” As tankers loiter near the battlespace, SMART tankers will initially serve as communication relays, followed by the addition of datalink translation for communication with the Multisensor Command and Control Constellation equipped with advanced electronically scanned array radars. In fact this technology will not wait for the new tanker. In March 2002, the service reported plans to acquire twenty Roll-on Beyond-Line-of-Sight Enhancement (ROBE) units in 2003 to relay communications. (Block, 2002) Secretary Roche later said the Air Force planned to outfit 40 KC-135 tankers with this capability. General Jumper, Chief of Staff of the Air Force, told reporters that these first tankers would serve as a kind of “IP (internet protocol) address in the sky” to help reduce satellite bandwidth requirements. Initially they would be used as Local Area Networks for transmission of electronic data between other platforms and a Combined Air Operations Center (CAOC). (Wolfe, 2002)

The Air Force now plans to simultaneously develop (spiral development) a new tanker and a new intelligence gathering aircraft. Northrop Grumman, Boeing and Raytheon met in March 2002 to develop plans for these systems, both of which will be able to direct unmanned aircraft. With spiral development these roll-on, roll-off pallets

would be developed and incorporated on a case-by-case basis on the future tanker. To jump-start the program the pallets will initially be used on KC-135s in the near term.

The multi-sensor command and control aircraft (MC2A) would emerge as a multi-spectral intelligence gathering and command and control aircraft. Future versions would incorporate a combination of high and low frequency long-range radars on a single aircraft allowing it to combat stealthy cruise missiles. The MC2A active emitter aircraft would combine the aerial watch mission of the AWACS with the ground surveillance mission of the Joint-STARS – currently on a modified Boeing 707. Because of this initiative, the Air Force is considering capping the JSTARS aircraft at 15 aircraft instead of the originally planned 19. According to Secretary Roche, a former Northrop Grumman executive intimately familiar with Joint STARS, the biggest problem with the JSTARS program is that the 707 it is mounted on costs as much as \$100 million apiece to remanufacture. Capping the program until a future tanker is online is an effort to transfer that money into acquiring a new aircraft instead of remanufacturing an old one.

(Muradian, 2001) A passive version of the MC2A would meld the RC-135 Rivet Joint electronic intelligence gathering mission, the Combat Sentry electronic analysis mission and the Cobra Ball long-range infrared sensing mission effectively extending the future tanker to cover six missions currently spread across other airframes. All of the variants would be able to pass on electronic information from UAVs flying over heavily defended areas. By working with more than one UAV the information could be linked more effectively increasing the speed of identifying targets and rapidly reducing aiming errors. (Fulghum, 2002a)

EADS (Airbus) is reportedly not submitting data on “SMART Tanker” or intelligence-gathering derivatives of its aircraft. Boeing subsequently has an advantage in this area. Boeing already has plans for a tanker that could fly around the world full of boxed, unmanned reconnaissance and strike aircraft and/or ferry five or six unmanned vehicles. Then it could refuel both manned aircraft and UAV’s and carry a battle staff – used to direct these aircraft in their strike or reconnaissance mission. (Fulghum, 2002b) General Jumper believes this concept will eventually enable manned aircraft to control unmanned aircraft and create a network in the sky to pass information to all assets in the battle space. The addition of the SMART tanker concept to the proposed \$20 billion to \$26 billion price tag for a 767 version tanker could increase the price tag even further, increasing the debate about the merits of a hasty purchase or lease of a fleet of aircraft, regardless of the capabilities.

4.2.5 Threat Protection

When buying a new military aircraft you would never consider buying antiquated systems. Therefore, the new aircraft would not only require GATM compliance, state-of-the-art navigational equipment, avionics and flight controls, but also proper threat protection. Today’s mobility aircraft are exposed to extensive enemy threats that they were not exposed to in the past. Tankers fly as close as possible to the battle space to ensure adequate refueling capability for fighter, reconnaissance and in the future long-range UAVs. The draft CDARA program document projects threats to the proposed system range from small arms to surface to air missiles (to include MANPADS), air defense artillery, fixed and rotary wing aircraft, directed energy weapons, integrated air defense systems, nuclear, biological, and chemical weapons (NBC), and information

warfare. The primary threat is MANPADS, man-portable air defense system, and long-range fighter aircraft. SPM and threat warning, if not in original package, are required future capabilities. (AMC/XPR, 2002: 11,12) With the SMART tanker mission would come increased protection requirements for the tankers, which may be met by AMC's Large Aircraft Infrared Countermeasures (LAIRCM) program. LAIRCM is a system built for large airplanes that directs countermeasures and provides advanced missile warning. Although the LAIRCM system is expensive, AMC has as its goal an incremental upgrade for all AMC aircraft based on funding. (Wolfe, 1999) For years crews have called for increased raw gear for AMC assets, especially those flown into or around the combat zone. It seems this is AMC's plan for the future.

Chapter 5 – Conclusions and Recommendations

This research effort began with a question: *What future capabilities will be necessary in tomorrow's Air Force tanker to meet the sophisticated and complicated needs of the Air Force and the military into the 21st century?* The research shows that there is an incredible amount of information out there on what the future tanker could provide. Some of it almost seems to be in the realm of science fiction. What we have to remember is that today's science fiction is tomorrow's reality. When the original flying boom was developed by Boeing, creating the tanker concept we know today, it began as a way to get our bombers to the fight, the nuclear fight. Today's tankers can still do that mission, but no longer is this considered a very likely scenario nor is it even talked about in most current doctrine or literature, except in a historical sense. Aerial refueling has become the backbone of force projection for the United States military. With the military draw down and the reduction in foreign basing, aerial refueling is essential to effective execution of today's missions, and I mean almost all combat missions.

The KC-135 Stratotanker has served us well for many years will continue to contribute for many years to come. But we have to understand the military requires more. The KC-135 has been plagued with mechanical problems, corrosion, aircrew shortages, antiquated systems causing depot delays, and a myriad of things that are, frankly, normal for an aircraft of this age. But what do we do about it? Can we afford to replace the KC-135s with a newer aircraft? You have read about the options the Air Force has on the table. They include upgrading the KC-135 for years to come with new engines, better avionics and more focused logistic systems to improve spare parts stock and decrease cannibalization. There are also the other options of buying a new

commercial off-the-shelf aircraft and modify it for the tanker mission, and using the same airframe for additional missions which the airframe is suited for, to reduce acquisition cost while at the same time modernize the entire fleet for maximum effect. We also have the side options of contracting a large or small portion of our aerial refueling capability from a civilian source and/or maintaining our current fleet until a totally new military tanker aircraft can be researched and developed using the same type acquisition system used to develop the C-17 and the C-130J models. There is always the issue of cost but due to the unavailability of cost data on much of the current projects I will be limiting my recommendations to capability only.

Table 7. Tanker Airframe Capability Chart

Capability Measured	KC-135	767	330	BWB*	Box Wing*
Number of Engines	1	3	3	2	2
Infrastructure Costs	1	2	3	5	4
Noise	4	2	1	3	3
Worldwide Demand	2	1	1	3	3
Cargo Capability	4	3	3	2	1
Boom Technology	3	2	4	1	1
Hose/Drogue	3	2	2	1	1
Fuel Load	4	3	3	1	2
Multi-point Capability	4	2	3	1	1
Threat Protection	5	4	3	1	2
SMART Tanker Capability	4	3	3	1	2
Acquisition/Upgrade Cost	1	2	3	5	4
Average Rating	3.00	2.42	2.67	2.17*	2.17*
* These two aircraft are concept aircraft. Ratings are based on estimated data that may prove to be incorrect.					

The tanker capabilities chart (seen above) is a numerical rating of each individual platform based on all the capabilities this research showed was an issue for the next generation tanker. Each aircraft was rated on a 1 to 5 rating scale (1 being best, 5 being

worst), based on its current or projected ability in each area. If aircraft were given the same rating then the capabilities were comparable and no difference would result from either's purchase. The average rating is the average number of the ratings in all areas. The lower the average rating number is, the better the aircraft should perform overall. However, the chart has several weaknesses that must be considered. First, every capability carries equal weight in the calculations, and it is obvious some areas are more important than others, like cost. Second, the data for the BWB and Box Wing aircraft are only corporate estimates since they are not currently in production. Also not considered is the American tendency to favor American industry over foreign industry when buying military hardware. Obviously this table is an attempt to produce a "big picture only" quantifiable rating for the platforms being considered.

Until recently, post September 11, the Air Force has always maintained that the KC-135s would be sufficient to last for 20 more years with the appropriate upgrades and maintenance. With the recent downturn in the economy, and the subsequent idleness of the commercial aircraft industry, some supposedly attractive offers have become available to the Air Force for replacing 100 tankers (older E models) with tanker modified Boeing 767s. I believe this is a tremendous step forward in capability, not to mention the possibilities for spiral development of other SMART tanker prospects. Therefore, before I talk about the required capabilities, I would like to put forward my opinion of the best option for the Air Force tanker procurement predicament. I believe that the answer is a combination of several options. First, I would keep the R model KC-135s since only a little more depot time will be required to bring these planes up to speed. They have a proven track record and it would be a much cheaper option than replacing

them after the investment into upgrading them has already been spent. While the KC-135 has the worst average rating in the chart above, the cost advantages and the capability gap that would be produced were they to all be scrapped immediately are compelling evidence they R models should be maintained for at least five or 10 years until a suitable replacement can be purchased. Second, I would continue the proposed replacement of the KC-135E models with 100 Boeing 767s modified as tankers. As you can see from the chart above, the 767 has the best rating of the currently available tanker options. I would use these 767s to bridge the gap between the KC-135 and the future military tanker for 2020. The Air Force should closely study the different prospects, to include Boeing and Airbus commercial derivatives as well as the advanced blended wing body and box wing aircraft concepts put forth by Boeing and Lockheed Martin. If this study says the 767 can be the tanker which can handle the dual role mission of the future Air Force then more can be procured. If it isn't capable then one of the other options can be used.

Now, during this transition, it is impossible for me to ignore the civilian "tanker for hire" concept being offered by Omega Air, Inc. With no outside costs and a significantly less per-hour-cost the Air Force could have a reliable fall-back resource during times of contingency, crisis, war or just increased operations tempo. The Civilian Reserve Air Fleet has been a part of air mobility doctrine for years and has been very effective. What would be the difference? It could pick up the business that the Air Force isn't quite interested in – like Navy exercises, etc, and could free up Air Force assets, which are notoriously overworked. It might even reduce the workload on the aircrews and actually increase their quality of life.

There was ample documentation to show that there are certain capabilities that the next generation tanker must possess. If the KC-135 does continue indefinitely, the next tanker absolutely must provide a robust cargo carrying capability. Many missions require this capability and buying a new aircraft without, at least, minimum capability would not be cost effective. The KC-10 is a tremendous example of what a cargo carrying capability provides from a planner's perspective.

Second, there must be the capability to switch between hose-and-drogue and boom operations and vice-versa in-flight. The KC-135s inability to switch between boom and drogue operations in-flight significantly increases the tanker planning problems when there are both boom and drogue aircraft in the same operation, which is almost always the case when the Navy or NATO aircraft are involved. Another desired capability is the ability to refuel two aircraft simultaneously, at least from wingtip hose-and-drogue ports. The time saved with simultaneous operations is invaluable to tanker planners. Receiver aerial refueling is another must. One of the most contentious scheduling restrictions is a tanker giving out all its gas quickly and having to return to refuel. This eats up crew duty time as well as makes it necessary to provide another tanker to fill in during its down time. The KC-10 has proven that being able to top off their tanks from another tanker increases flexibility and tanker management exponentially and allows the aircraft to be effectively utilized over a longer period of time.

A topic of extreme interest recently is the "SMART" tanker. If the concept works as well as its proponents say it will then the 40 specific tankers, which are modified for the mission will be in high demand. There is no data on what special crew qualifications will be required, but if there are special qualifications required then crew and aircraft

scheduling may be impacted negatively. Also, JFACC's will want this capability up at all times and will probably give this mission priority over the aerial refueling mission. The capability is sorely needed but a better option might be to just make one base of KC-135s support this mission or even better put this capability on a smaller fleet of aircraft -- such as the KC-10s or the newly delivered 767 tankers, if purchased. With the amount of time the KC-135s are spending in depot now, any additional capability added only extends the time they are in depot and out of the picture. Also, the crew force of the KC-10 or the future 767 tanker will probably be better able to set up proper training to separate this unique mission from the refueling arena. The 767 could have the aircraft outfitted from the start when they roll off the assembly line and make this mission part of their original training course.

My final requirement is proper and complete threat warning and protection equipment. All aircraft in today's military are exposed to the threat. Our mobility forces -- C-17, KC-135, KC-10, C-130, etc. -- have all been within the threat area in Operation Enduring Freedom. Many of those aircraft do not have effective threat warning or defense capability. They are at the mercy of the enemy and have only sporadic CAP protection from the fighter community. Yes, defensive systems are expensive, but the loss of a mobility asset is an even worse prospect. Our first priority as an Air Force is to provide the aircrews the ability and training to properly detect and defeat the known threats of the enemy. Therefore, every current and future tanker, whatever it may be, should have the newest and best defensive system available.

As a final paragraph to this paper I must mention some flaws or assumptions that were made by me. One of the major problems is the total lack of cost data I used for the

acquisition of the Air Force's next tanker. While there was a myriad of information on capabilities as well as press releases available, there was very little cost data released. Therefore, I consciously chose to ignore cost in my analysis. I am not naïve enough to think it has no bearing on the final outcome. To the contrary, it will probably have the biggest impact of all aspects on the tanker's future. But, I thought a paper investigating the various positives and negatives of possible weapon systems would have merit as a starting point. Future research on this topic is needed. Other areas for further research should include extensive study on the proper mix of tanker aircraft in the Air Force inventory. Can we provide for three different tanker aircraft? Does this cause an inordinate amount of unnecessary expense? Also, which platform is best for implementing the SMART tanker concept? Another interesting subject is the dilemma about purchasing an aircraft (Airbus MRTT) built and designed by a foreign industry. What kind of ramifications would this have on American industry and political opinions? Finally, the advantages of spiral development of an aircraft and a mission platform should be more closely studied. Can the Air Force afford to have the same platform covering too many missions? Will this make us more vulnerable to possibly shutting down more than one mission if there is a problem with this aircraft type? In any case, I have said my piece, and I hope this information is worthwhile and helps decision makers choose the best solution to help our current aerial refueling problems.

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